Fast Ramp in the Main Injector

- Motivation:
  - Near term – NuMI: To increase the proton throughput
  - Long term – A step on the roadmap towards a 2 MW Main Injector in the Proton Driver era:
    - Beam intensity increase by a factor of 5
    - Cycle time reduction by 20%
    - Beam power increase by a factor of 6 to 2 MW
- Goal:
  - To reduce NuMI cycle time from 1.867 sec (28 Booster cycles) to 1.533 sec (23 Booster cycles).
  - To increase max pdot from 240 GeV/s to 280 GeV/s (which was revised from 305 GeV/s as originally assumed)

Fast Ramp in the Main Injector (cont…)

- Previous RF calculations for 5 cases: (J.G./W.C.)
  - 240 GeV/s, 3 x 10^{13}
  - 305 GeV/s, 3 x 10^{13}
  - 240 GeV/s, 6 x 10^{13}

    (assuming successful 12-batch slip stacking or barrier RF stacking)
  - 305 GeV/s, 6 x 10^{13}

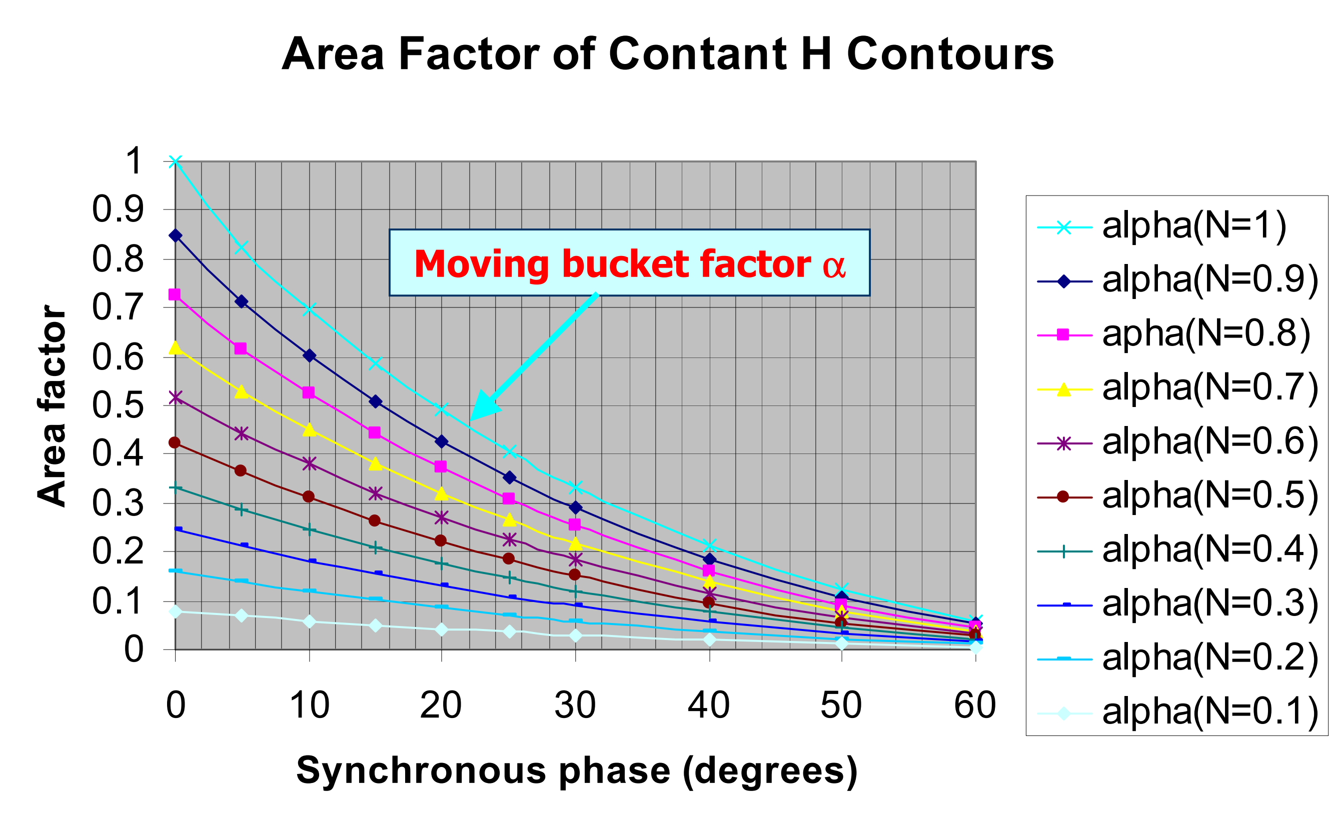
    (ditto)
  - 305 GeV/s, 1.5 x 10^{14}

    (goal of a 2-MW MI in the Proton Driver era, documented in TM-2169)
- New calculations:
  - 280 GeV/s, 3.3 x 10^{13}
  - 280 GeV/s, 4 x 10^{13}

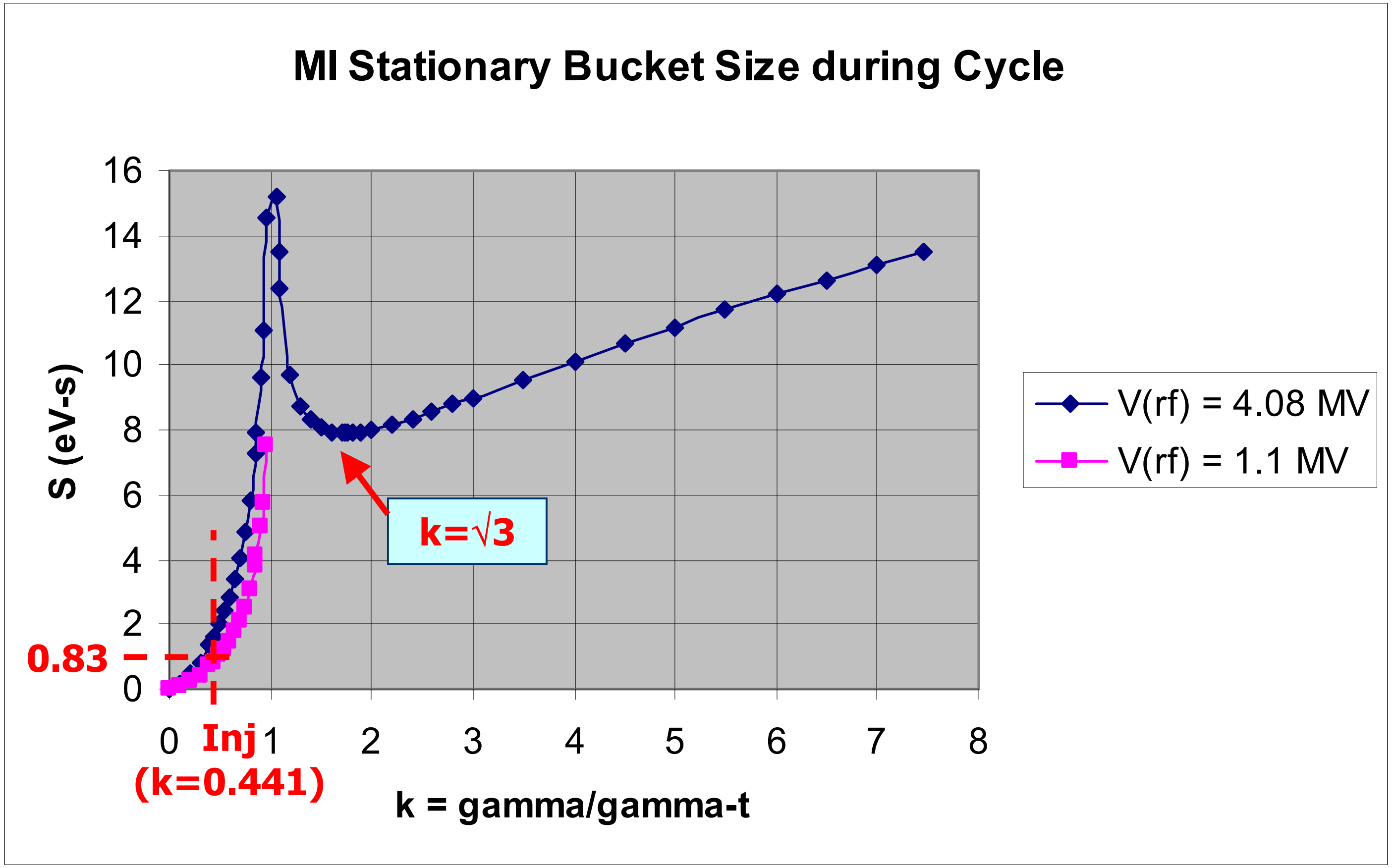
Fast Ramp in the Main Injector (cont…)

- **Bucket size calculation:**
  - Parameters:
    - $k \equiv \gamma/\gamma_t$ $\gamma_t = 21.6$
    - φ = synchronous phase, α = moving bucket factor (see attached plot)
    - **17 cavities**, each 240 kV for a total of 4.08 MV (but only 1.1 MV @inj)
    - **Bucket size ≥ 0.6 eV-s** (per I.K.)
  - Injection:
    - E = 8 GeV, γ = 9.526, k = 0.441
    - V(rf) = 1.1 MV, stationary bucket = **0.83 eV-s (inj)**
  - After transition, minimum stationary bucket occurs at k = √3:
    - V(rf) = 4.08 MV, minimum stationary bucket = 7.9 eV-s
    - At **240 GeV/s**, V = 2.67 MV/turn, φ = 40.9°, α = 0.208, moving bucket = **1.64 eV-s**
    - At **280 GeV/s**, V = 3.10 MV/turn, φ = 49.5°, α = 0.129, moving bucket = **1.02 eV-s**
    - At **305 GeV/s**, V = 3.38 MV/turn, φ = 55.9°, α = 0.085, moving bucket = **0.67 eV-s**
  - Before transition, k = √3 / 2 ⇒ same stationary bucket area as k = √3. So the maximum ramp rate can start here.

Fast Ramp in the Main Injector (cont…)



Fast Ramp in the Main Injector (cont…)



Fast Ramp in the Main Injector (cont…)

- **Power calculation:**
  - Parameters:
    - Cavity Q = 6500, R = 7.8 x 10^5 Ω, R/Q = 120 Ω
    - **17 cavities**, each delivering 200 kW for a **total of 3.4 MW**
    - Wall loss: V(gap) = 240 kV $\Rightarrow$ P(wall) = 37 kW each, or 0.63 MW for 17 cavities
    - **3.3 x 10^{13} and 4.0 x 10^{13}** (per I.K.)
  - Power requirement:
    - At **240 GeV/s, 3.3 x 10^{13},** P(beam)= 1.27 MW, P(wall) = 0.63 MW, P(total) = **1.90 MW**
    - At **240 GeV/s, 4.0 x 10^{13},** P(beam)= 1.54 MW, P(wall) = 0.63 MW, P(total) = **2.17 MW**
    - At **280 GeV/s, 3.3 x 10^{13},** P(beam)= 1.48 MW, P(wall) = 0.63 MW, P(total) = **2.11 MW**
    - At **280 GeV/s, 4.0 x 10^{13},** P(beam)= 1.79 MW, P(wall) = 0.63 MW, P(total) = **2.42 MW**

- **High Intensity Robinson stability:**
  - Parameters:
    - Anode power = 100 kW, wall loss = 37 kW $\Rightarrow$ dissipation = 137 kW each for a total of **2.33 MW**
  - Stability criterion:
    - Dissipation power > P(beam), which is **satisfied in all the cases**.

Fast Ramp in the Main Injector (cont…)

- Items for this meeting:
  - Operation requirement (I.K.)
  - Magnet power supply (D.W.)
  - RF (D.W./J.R./J.G.)
    - Voltage
    - Power
    - Bucket area (especially on the initial parabola where the bucket size is smallest due to a combination of limited RF voltage, low beam energy and small moving bucket factor)
  - Magnet (D.H.)
- Possible collaboration with MINOS:
  - D. Michael showed strong support to this project.